

ANALYSIS OF IUE OBSERVATIONS OF CS IN COMET BRADFIELD (1979 1)

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ABSTRACT

The CS high-resolution and low-resolution IUE data obtained on Comet Bradfield (1979 1) have been analyzed. The high resolution rotational band profiles can be fitted with theoretical band profiles which are derived using a Boltzmann temperature of 70 K. A very rapid variation with heliocentric distance, for the CS brightness has been found. The implications of these results for models of the coma along with the origin of the CS species are discussed.

INTRODUCTION

The first sulfur containing radical discovered in comets was observed in Comet West (1976 VI) during the rocket observations of Smith and Casswell (ref. 1). These initial results were later confirmed by IUE observations of Comet Seargent (1978 m) (ref. 2) and Comet Bradfield (1979 1) (ref. 3). The gas emission rate from Comet Bradfield (1979 1) was sufficient so that, contrary to the previous observations, high-resolution spectra of CS could be measured. Low-resolution spectra of the comet were obtained with the large aperture at different heliocentric distances and these spectra show that the CS emission appears as a point source.

OBSERVATIONS

The details of the IUE satellite instrumentation have previously been described (ref. 4) so that only the observational procedure will be outlined in this section. Several long wavelength high-resolution spectra were taken at various times using the large (10" x 20") aperture of the spectrograph. The comet was tracked on the center of its maximum brightness using the fine error sensor of the IUE. In all of the high-resolution spectra the photo-

write images showed a darkening in the region of the CS bands but only two exposures were obtained which exhibit sufficient signal to noise ratios so that useful data could be extracted from the tape. The CS bands actually occur in two different orders in the spectrum, one of which occurs near the center of the camera and the other near the edge. The quality of the CS image near the edge of the camera is severely degraded by the variation in the grating efficiency across its blaze. Nevertheless, some indication of the presence of the CS band was obtained.

One of the two high-resolution spectra that were analyzed is shown in Figure 1. The data have been averaged using a five point running mean. The spectrum clearly shows two peaks corresponding to the Q and R branches of the $X^1\Sigma \rightarrow A^1\Pi$ transition in CS. The overall width of both bands is greater than 0.2nm which is a factor of two to three times greater than the quoted instrumental bandwidth for an extended object. The actual instrumental bandwidth is probably less than the quoted value of 0.08nm since as Figure 2 shows the CS emission does not completely fill the large aperture of the spectrograph. This increases the effective resolution of the instrument because the CS emission serves as a narrower slit.

HIGH RESOLUTION THEORETICAL PROFILES

In order to interpret the observed band profiles, theoretical band profiles based upon the known CS spectrum and rotational line factors as given in Herzberg (ref. 5) were calculated. The observed CS spectrum at 257.5nm is a $X^1\Sigma \rightarrow A^1\Pi$ transition and thus shows P, Q and R branches. Because of the small rotational constant of CS, the lines are closely spaced, especially in the Q branch, where many lines are bunched together near the origin. The R and Q branches have heads at 257.60 and 257.77nm, respectively while the P branch shows no head.

A perturbation exists in the CS spectrum at the J=15 level in the 0-0 band. This was neglected in the present calculations of the rotational line factors (ref. 5) since it is unlikely to lead to a serious error in the fitting of the rotational profile. Only one or two lines at relatively high values of J, will be affected by this perturbation so that only one or two lines in the total spectrum will be distorted.

It was assumed that the rotational energy could be described in terms of a Boltzmann temperature. Spectral profiles were built up using a Lorentzian form for each individual line, the width of which equalled the slit width of the IUE spectrometer. The actual profiles were constructed on a PDP-11/03 computer with a VT 55 graphic display terminal. Theoretical profiles were calculated using a Lorentzian bandwidth varying from 0.001nm to 0.08nm. The best fit for the shape, wavelength and relative heights of the Q and R bandheads occurred when a HWHM bandwidth of 0.02nm was used. This is in reasonable agreement with the low-resolution results which show that HWHM of the intensity peak for the observed CS (0-0) band fills only $\frac{1}{2}$ of the long side of

produced vibrationally excited to $v'' < 7$ and that the branching ratios for reactions (1) and (2) are 20% and 80%, respectively. The absorption coefficient for this band has been measured (ref. 9). When it is combined with the higher solar flux (ref. 10) in this region, one can compute a photochemical lifetime at 1AU of 103 sec. At the largest observed heliocentric distance and with a 1km/sec outflow velocity this corresponds to a scale length of 88 km, well below the resolution of the present observations.

DISCUSSION

The CS molecule is the first diatomic molecule with an allowed infrared transitions that shows any evidence that it has retained memory of the temperature at which it was formed. In light of the fact that CS is produced via photodissociation in high vibrational levels (ref. 7) it is likely that the observed "temperatures" are the result of radiative cascade from these higher levels. Thus one needs a detailed knowledge of the photodissociation dynamics to include the effect of these cascade processes in any radiative equilibrium model of the coma of the comet. Only when this is done will one be able to evaluate how collisions can contribute to the observed temperatures.

The photodissociation model of CS₂ can also explain the presence of S atoms in the comet since these atoms are the products of the photodissociation of both CS₂ and CS. Most of the S atoms are produced in the ¹D state which has a radiative lifetime (ref. 11) of 25 sec. However, because of this short lifetime and the relatively low sulfur abundance it is unlikely that ¹D atoms can be detected directly as in the case of carbon (the ¹D-¹P transition at 193.1nm) where the lifetime of the ¹D state is 3200 sec (ref. 12). It is possible that resonance fluorescence mechanism may excite the (¹S-¹D) transition at 7725Å since this transition has a lifetime of only 0.47 sec (ref. 11) and the analogous D atom transition has already been observed.

CONCLUSION

The detailed analysis of both the high- and low-resolution CS data obtained during the observation of Comet Bradfield (1979 1) suggests that this radical is produced by photodissociation of CS₂. The heliocentric variation of the CS brightness is consistent with this conclusion along with the presence of S atoms in comets. Further analysis of the data may reveal how important collisions are in the inner part of the coma.

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TABLE 1

Heliocentric Variation of the Average Brightness of
the CS (0,0) Band

<u>Heliocentric Distance, r (a.u.)</u>	<u>Geocentric Distance, Δ(a.u.)</u>	<u>Average Brightness (kR)</u>	<u>Derived CS Prod- uction Rate (sec^{-1})</u>
0.71	0.615	2.1	1×10^{26}
0.80	0.40	1.2	5×10^{25}
0.925	0.20	2.6	1.6×10^{25}

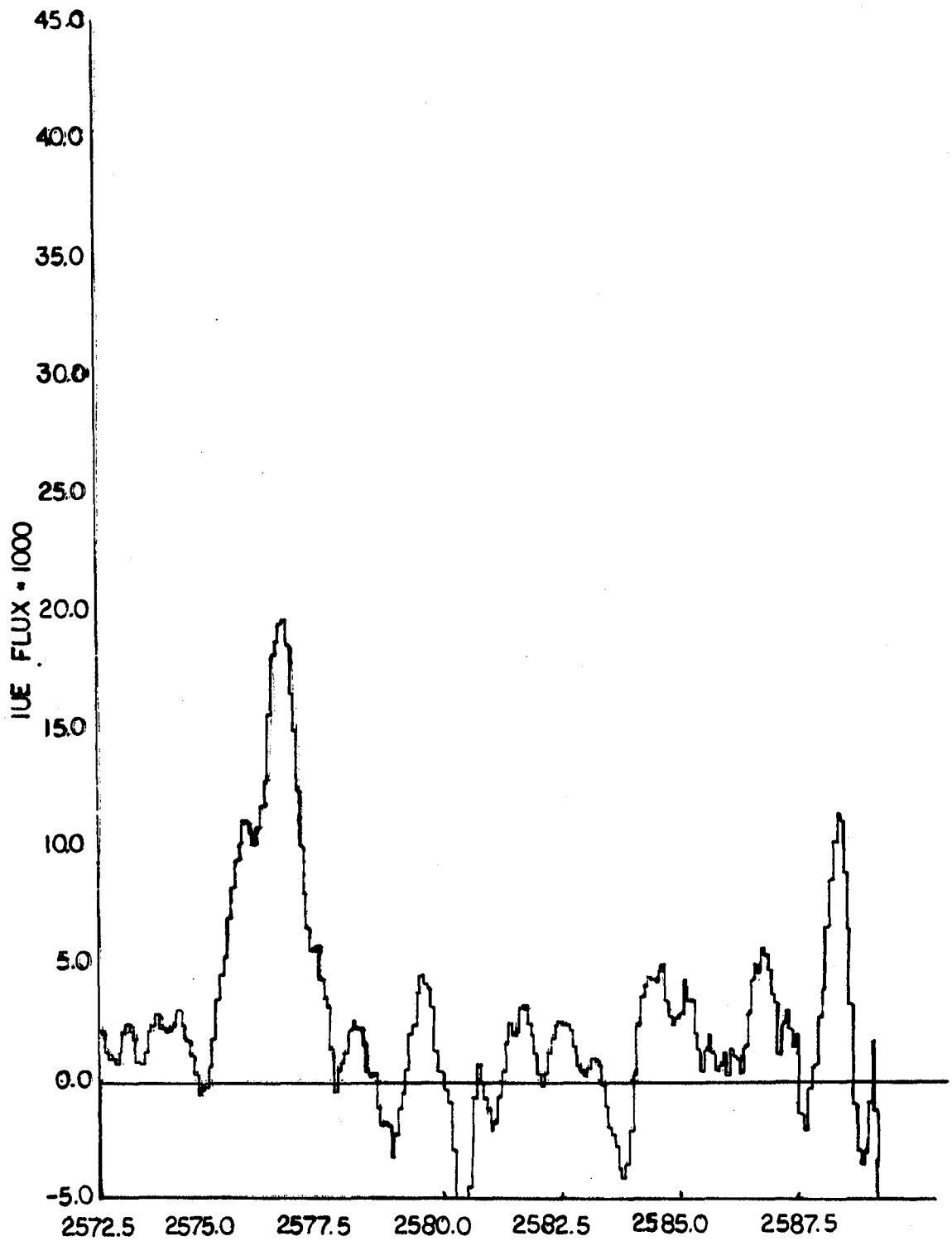


Figure 1.

High-resolution IUE Spectra of Comet Bradfield (1979 1) in the CS region.

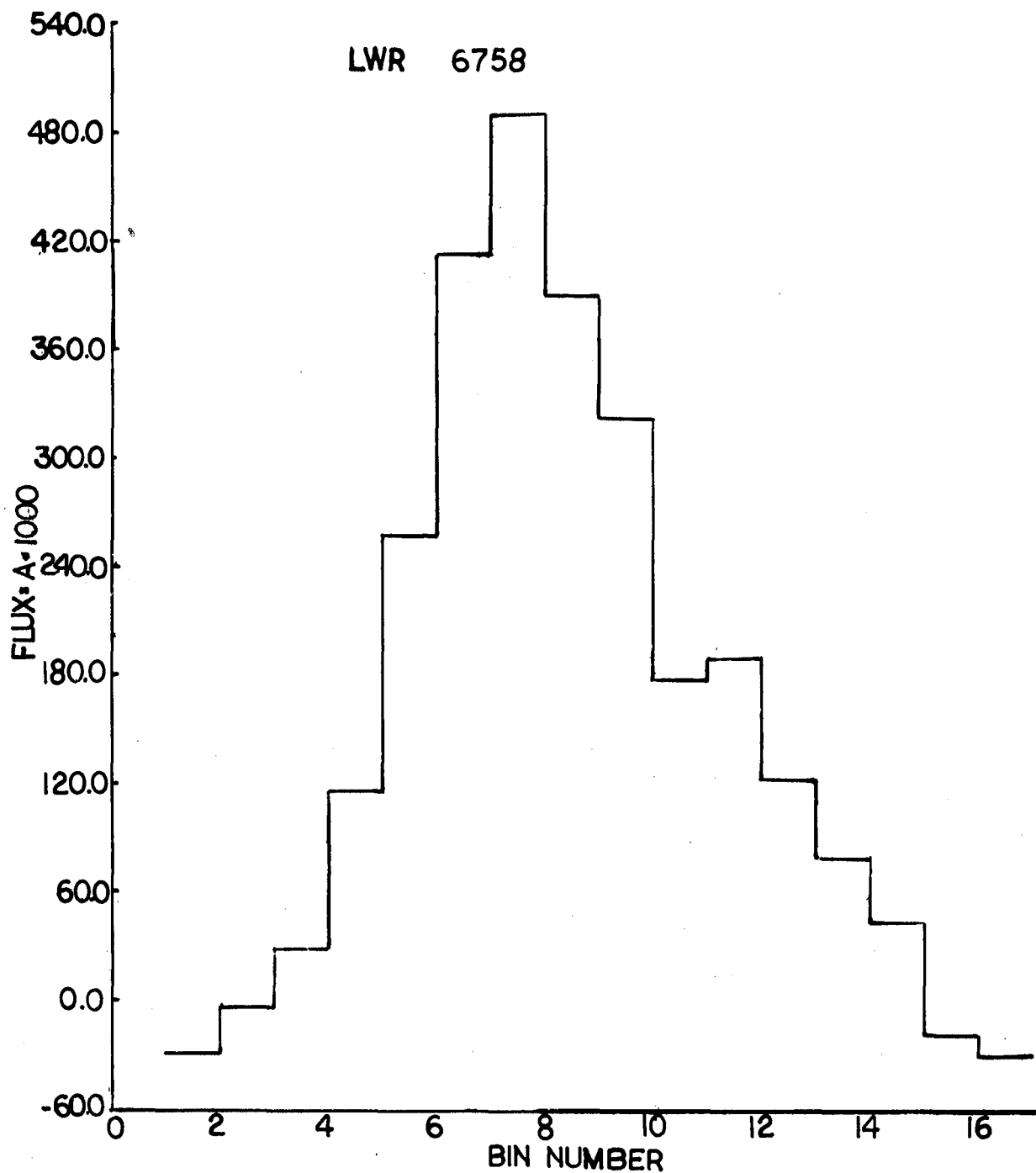


Figure 2.

Spatial profile of low-resolution spectra of CS scanned along the long dimension of the slit.

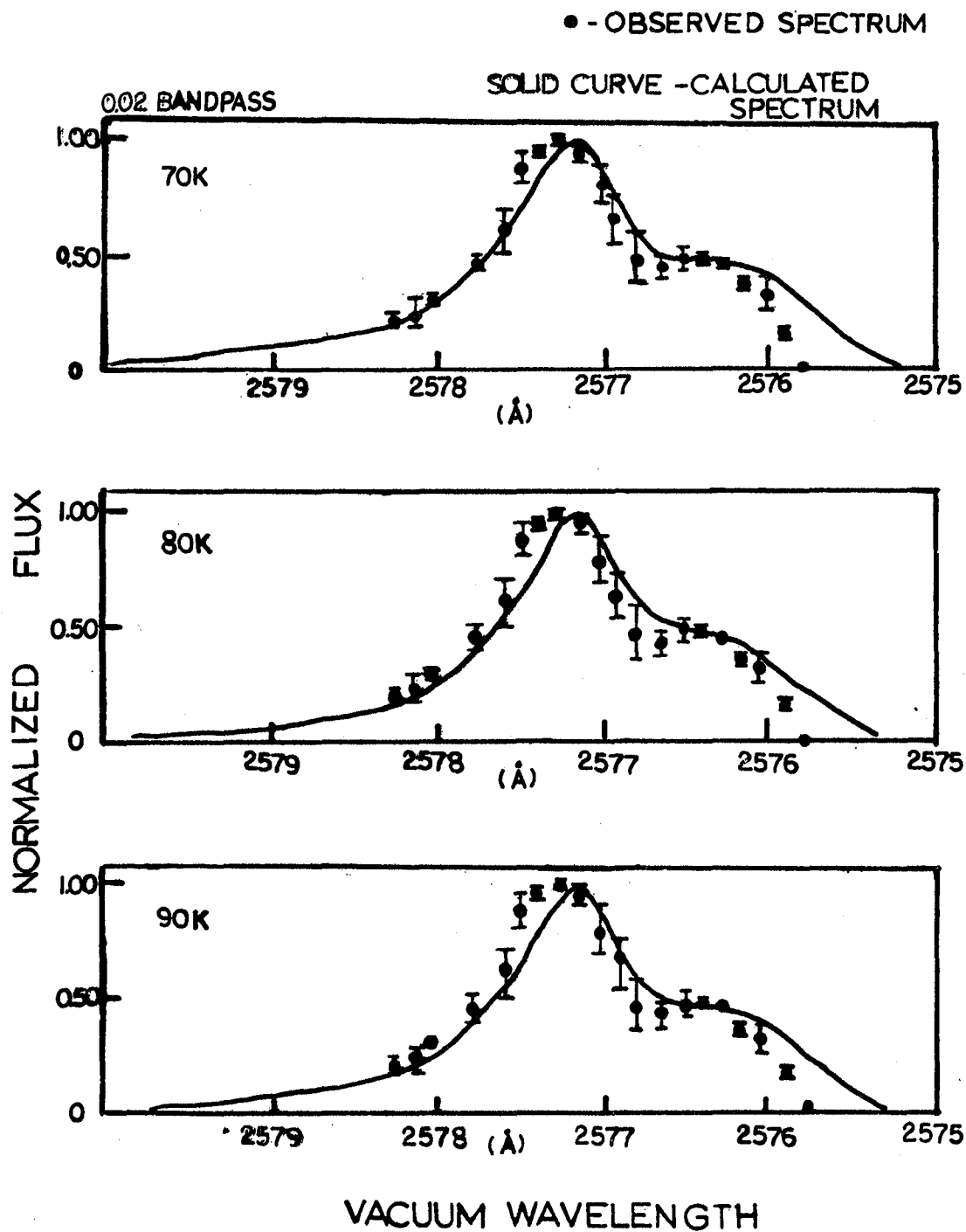


Figure 3.

Comparison between observed and theoretical CS band profiles for 0.02nm HWHM bandpass and at temperatures of 70, 80, and 90 K.